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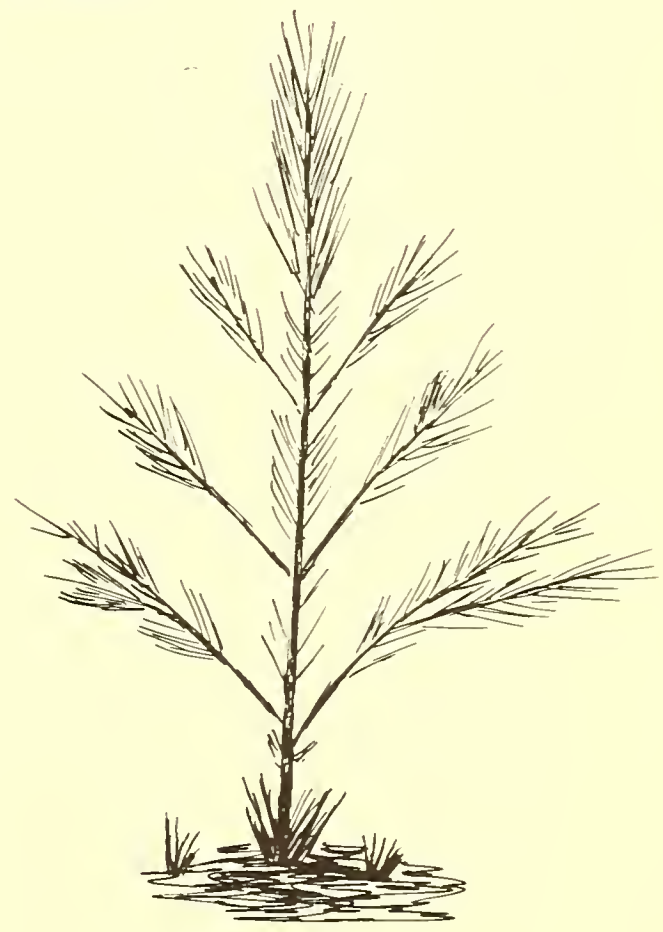
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This paper is condensed from a dissertation submitted in partial fulfillment of the requirements for the Ph. D. degree at Duke University. The author wishes to express his appreciation to Charles W. Ralston, Associate Professor of Forest Soils in the School of Forestry, for advice and guidance in this study.

Spacing - Environmental Relationships in a Slash Pine Plantation X

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by

William R. Harms

INTRODUCTION

The influence of tree spacing on the relationship between diameter growth and prevailing environmental conditions was investigated in a 6-year-old slash pine (Pinus elliotii Engelm. var. elliotii) plantation on the George Walton Experimental Forest, Dooly County, Georgia. The study was designed to determine whether differences in diameter growth between three spacings were related to soil moisture, rainfall, evaporation, wind, and soil and air temperature.

In many areas of the South soil moisture frequently becomes limiting to growth at sometime during the growing season, whereas light, temperature, and other environmental factors generally are adequate. Because of this, considerable emphasis was placed on the growth-soil moisture aspect of the study in an attempt to provide a basis for evaluating the importance of moisture to young plantation growth in the middle coastal plain area of Georgia.

Tree growth-soil moisture relationships have received considerable attention in recent years. Many studies have been made in both natural stands (2, 3, 5), and plantations (4, 8, 9, 14). Zahner and Whitmore (14) reported that widely spaced trees in a radically thinned loblolly pine (Pinus taeda L.) plantation in Arkansas made diameter growth into late fall while unthinned control plots ceased growth by midsummer. They were able to relate growth to crown and root development following thinning, and to available soil moisture. On the control plots the soil dried very rapidly, nearing the wilting point by midsummer, while moisture on the thinned plots remained high until late summer or early fall. Della-Bianca and Dils (4) found that radial growth of planted red pine (Pinus resinosa Ait.) continued longer in thinned than in unthinned stands. They attributed this in part to more favorable soil moisture conditions in the thinned stands resulting from reduced interception and less root competition. McClurkin (9) reported similar results from a thinning study in shortleaf pine (Pinus echinata Mill.) plantations in Mississippi.

No work of this kind has been published for the south Atlantic coastal plain, or for slash pine. Since slash pine is the most widely planted of the southern pines, this study was undertaken to gain a better understanding of the interrelationships between plantation spacing, environmental conditions, and the diameter growth of this species in the middle coastal plain of Georgia.

METHODS

The investigation was made during the growing seasons of 1957 and 1958 in a slash pine plantation spacing study established on the experimental forest in 1952 (1). The parent study was planted in 3/4-acre plots of a randomized block design in a field that had been under cultivation the previous year. Two blocks (A and B) were established, with each block consisting of one plot for each of eight different spacings. Both replications of the 6 x 6-foot (1,210 trees per acre), 8 x 8-foot (681 trees per acre), and 15 x 15-foot (194 trees per acre) spacings were chosen for study.

Soils on the study area belong to the Gilead and Lakeland series. These are somewhat well to excessively drained loamy sands derived from irregularly bedded sands, clays, and gravels of the middle coastal plain. Thickness of the surface layer varied from 10 to 30 inches.

A rectangular plot 0.2 acre in size was established in each spacing for diameter growth and soil moisture measurements.

Aluminum growth bands (7) were attached at d. b. h. to ten trees in each of the six plots. Growth to the 0.01 inch was recorded weekly from March through October of both years.

Soil moisture was determined gravimetrically from tube samples (10) collected at four randomly selected spots in each plot. Samples were taken at 2- to 3-day intervals from the 0- to 6-, 6- to 12-, and 12- to 18-inch layers, and at biweekly intervals from the 30- to 36- and 48- to 54-inch layers.

Three 3-inch core samples were taken from each plot and sampling depth for bulk density and 0.06 and 0.3 atmosphere tension determinations. Composite bulk samples were also collected and analyzed in the laboratory for texture and 15-atmosphere moisture content.

A weather station was installed near the study area to provide daily records of air temperature and relative humidity, soil temperature at depths of $\frac{1}{2}$, 6, and 24 inches, rainfall, and open pan evaporation. A totalizing anemometer was installed at crown height in the center of the study area. Complete records of soil temperature, evaporation, and wind were not obtained for 1957; consequently, these factors were included only in the 1958 analysis.

The relationships between diameter growth, soil moisture, and the various weather factors were analyzed by multiple regression techniques. Each spacing was first analyzed by year. Differences between spacings were then tested by combining data from all spacings into a single regression equation for each year.

Spacing comparisons were made by setting up orthogonal linear and quadratic components of the combined data as additional variables, and making the appropriate F-tests. The linear component tested the hypothesis that there was no difference between the 6 x 6 and 15 x 15 spacings. The quadratic component tested the hypothesis that the 8 x 8 spacing did not differ from the average of the other two. Additional variables were set up as interactions of linear and quadratic terms with each of the environmental variables. These interactions tested the hypotheses with respect to each of the variables.

Fifteen independent variables were selected for initial analysis. These variables, tabulated below, were chosen from scatter diagrams of diameter growth rate plotted over each of the environmental factors.

Diameter growth variables

1957 and 1958

- Y = Mean daily diameter growth rate in 0.001 inch for the 7-day period prior to a soil sampling date.
- X₁ = Block effect = Block A minus Block B.
- X₂ = Available water = The summation of the five sampling depths of the available water in inches divided by depth in inches.
- X₃ = Average daily maximum air temperature for 7 days prior to a soil sampling date.
- X₄ = (X₃)²
- X₅ = Average daily minimum air temperature for 7 days prior to a soil sampling date.
- X₆ = (X₅)²
- X₇ = Sum of the rainfall occurring during the 14 days prior to a soil sampling date.

- X_8 = Average daily maximum vapor pressure deficit for 7 days prior to a soil sampling date. (Calculated from relative humidity data.)
- X_9 = Seasonal effects = The day number from January 1 on which a given soil sample was taken.
- X_{10} = $(X_9)^2$

1958 only

- X_{11} = Average daily evaporation in inches for 7 days prior to a soil sampling date.
- X_{12} = Average daily wind in miles per day for 7 days prior to a soil sampling date.
- X_{13} = Average daily mean soil temperature at a depth of one-half inch for 7 days prior to a soil sampling date.
- X_{14} = Average daily mean soil temperature at a depth of 6 inches for 7 days prior to a soil sampling date.
- X_{15} = Average daily mean soil temperature at a depth of 24 inches for 7 days prior to a soil sampling date.

RESULTS

Environmental Factors

Spring moisture was higher on all plots in 1958 than in 1957. Except for short drying periods in early July and late August, available water in the profile generally exceeded 4 inches throughout 1957 in all spacings (fig. 1). Moisture was high in March and April of 1958, with 7 to 9 inches of available water. There was a gradual decrease during the remainder of the season as the profile approached a low of about 3 inches in October. At no time during the study was moisture in the entire profile reduced to the wilting point. Physical properties and moisture characteristics of the soils are presented in table 1.

Normal growing season rainfall (March - October) for the experimental forest is 33.58 inches. Rainfall was 5.30 inches above normal in 1957, and 3.75 inches below normal in 1958. Trends of the other environmental factors are presented in figure 2.

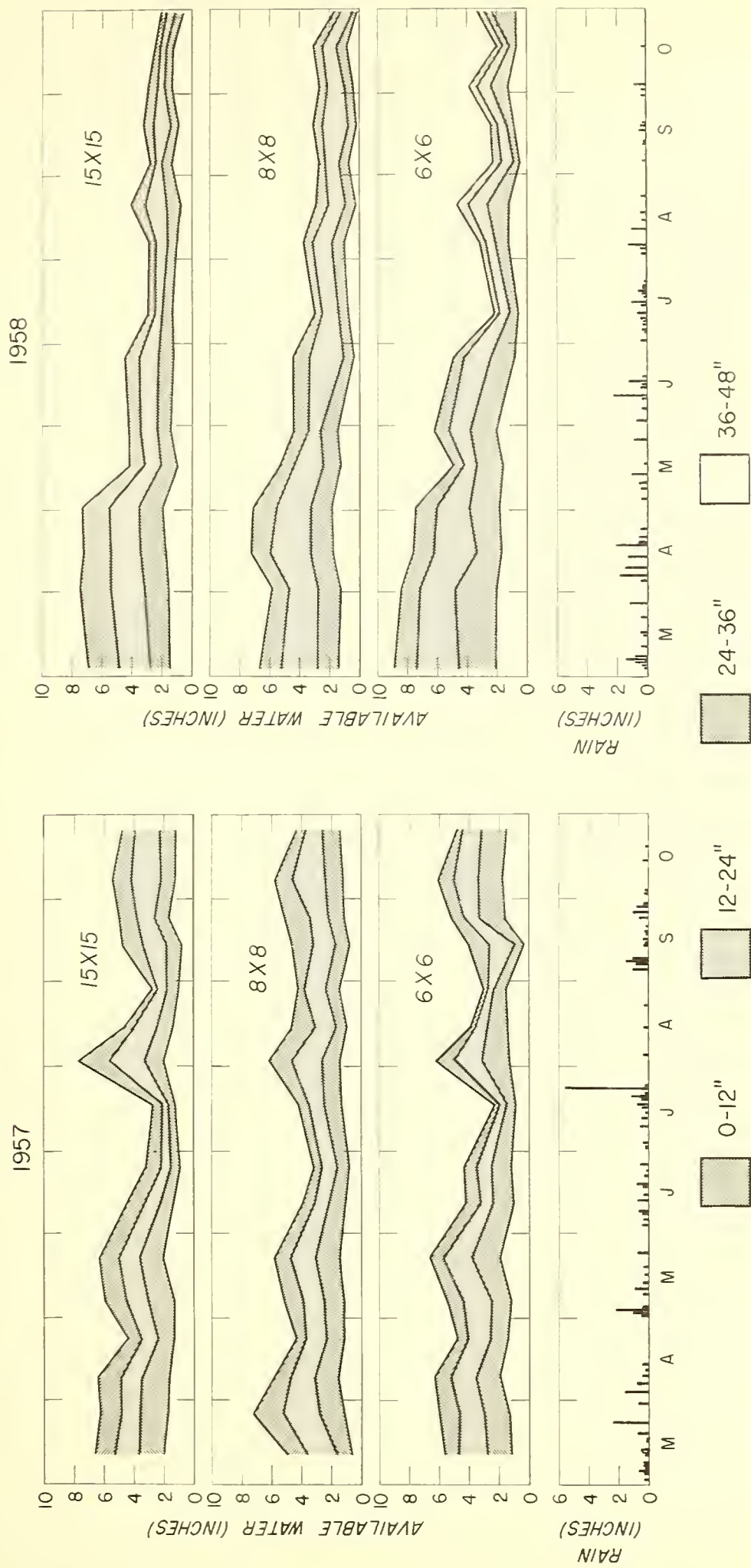


Figure 1.--Seasonal soil moisture curves by spacing and year showing rainfall and available water by 12-inch depths for the first four feet of soil.

Table 1. --Some physical properties of the soils on the study plots

Plot	Depth	Texture ^{1/}	Bulk density	Moisture content in atmosphere tension of--		
				0.06	0.3	15.0
	<u>Inches</u>			<u>----- Inches -----</u>		
A 6 x 6	0 to 6	LS	1.49	1.09	0.30	0.13
	6 to 12	LS	1.59	.87	.34	.13
	12 to 18	LS	1.61	1.26	.41	.18
	30 to 36	SCL	1.79	1.62	1.22	.87
	48 to 54	SCL	1.79	1.56	1.16	.84
B 6 x 6	0 to 6	LS	1.51	.87	.33	.10
	6 to 12	LS	1.56	1.24	.35	.12
	12 to 18	LS	1.59	1.05	.37	.13
	30 to 36	SCL	1.74	1.54	1.01	.68
	48 to 54	SC	1.72	1.67	1.56	1.10
A 8 x 8	0 to 6	LS	1.46	.95	.32	.11
	6 to 12	LS	1.60	.72	.39	.16
	12 to 18	SL	1.63	1.18	.72	.40
	30 to 36	SC	1.59	2.07	1.79	1.19
	48 to 54	SC	1.68	2.19	2.15	1.41
B 8 x 8	0 to 6	LS	1.47	1.28	.32	.11
	6 to 12	LS	1.61	1.05	.36	.16
	12 to 18	SL	1.62	.97	.53	.30
	30 to 36	SC	1.62	1.95	1.49	1.08
	48 to 54	SCL	1.79	1.82	1.51	1.05
A 15 x 15	0 to 6	S	1.53	.82	.27	.09
	6 to 12	S	1.63	.67	.30	.12
	12 to 18	LS	1.62	.59	.30	.12
	30 to 36	SC	1.72	1.68	1.62	1.22
	48 to 54	SC	1.79	1.73	1.64	1.17
B 15 x 15	0 to 6	LS	1.64	.89	.60	.22
	6 to 12	SL	1.63	1.52	.82	.38
	12 to 18	SCL	1.60	1.62	1.24	.77
	30 to 36	C	1.72	1.95	1.93	1.43
	48 to 54	SC	1.73	1.94	1.72	1.11

^{1/} S = Sand; C = Clay; L = Loam.

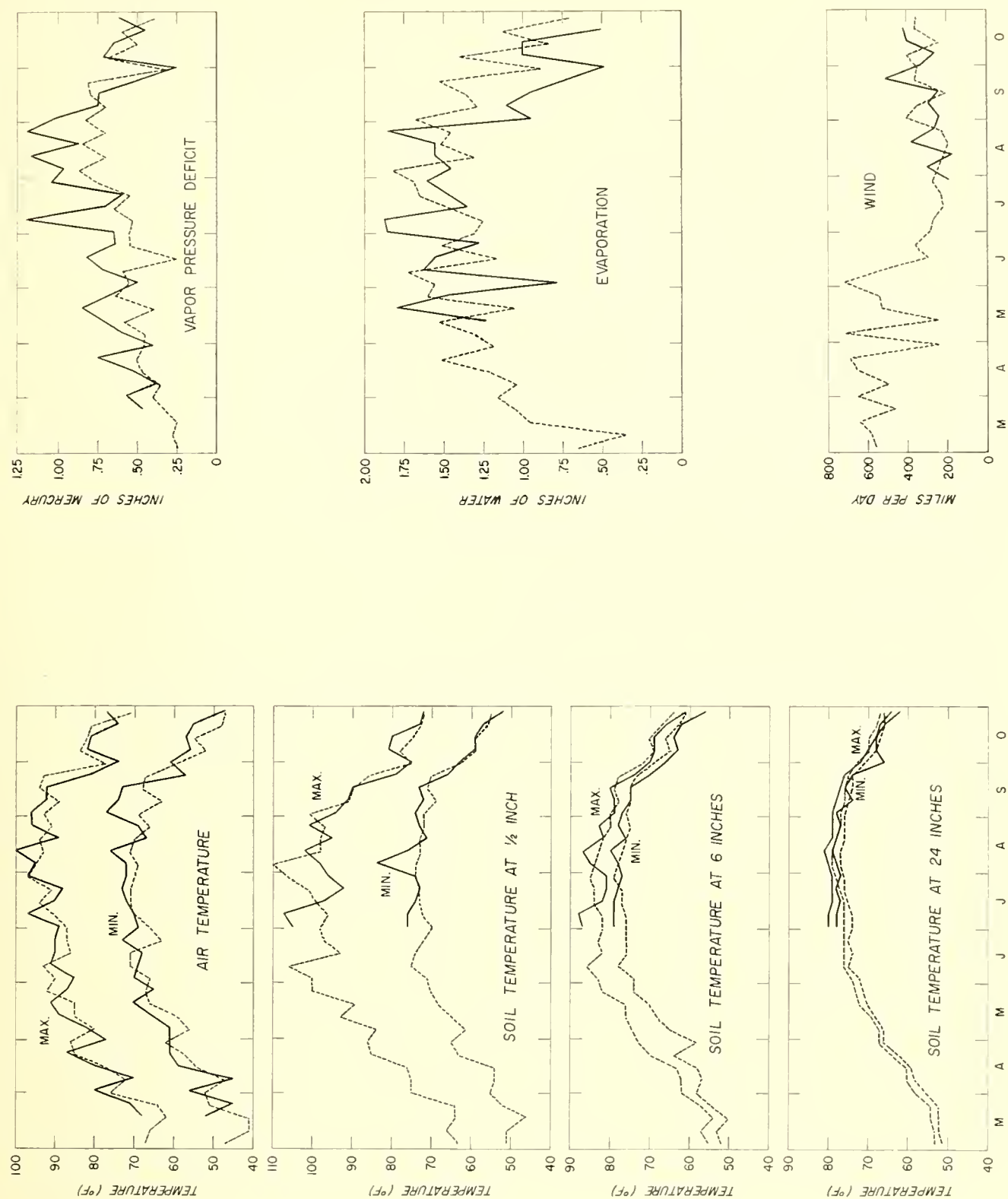


Figure 2.--Seasonal trends of the environmental factors measured in 1957 (——), and 1958 (-----).

Growth

Diameter growth in 1957 was somewhat unusual in that the curves were linear rather than the usual sigmoid type (fig. 3). High rainfall and soil moisture, especially during the summer, may account for this. Lack of the sigmoid relation also may be due in part to failure to start measurements early enough in the season. Growth during 1958 followed the sigmoid pattern quite well, with a slow increase in the spring, and a period of rapid growth in early summer, followed by a gradual decline in late summer and fall. Except for the last week or two in the fall, all spacings made measurable growth throughout both growing seasons.

In 1957, 75 percent of the growth of the 6 x 6 spacing was completed in early August. In 1958, 75 percent of the growth was completed by early June. The 8 x 8 and 15 x 15 spacings completed 75 percent of the growth by late August in 1957. In 1958, these spacings had completed 75 percent of their growth by late June and mid-July, respectively.

Average diameter of sample trees in each plot at the beginning of each season, together with average growth, is shown in table 2. Basal area in square feet per acre and basal area growth are shown in table 3. On the basis of average growth per tree, the relationship between basal area and spacing is the same as that of diameter growth. The trend is reversed on the acre basis.

Statistical Analysis

Analysis of variance of individual regression equations for 1957 showed that available moisture accounted for most of the variation in growth rate of the 6 x 6 and 15 x 15 spacings, and rainfall accounted for most of the variation in the 8 x 8 spacing. Of the remaining variables, only air temperature and seasonal effects were significant.

In 1958, available moisture again accounted for most of the variation in growth of the 6 x 6 and 15 x 15 spacings, and rainfall for most in the 8 x 8 spacing. Evaporation was the second variable removed; it was significant in the 6 x 6 and 15 x 15, but not in the 8 x 8 spacing. Maximum air temperature was third in order of significance in the 6 x 6 and 8 x 8 spacings, and block effect in the 15 x 15 spacing. Seasonal effects were removed last.

There are a number of reasons for nonsignificance of so many of the variables. Foremost probably are large measurement and sampling errors in growth and soil moisture observations. In such a situation variables must be strongly correlated and cover a wide range of values to show statistically significant relationships. Because of the uniformity of the climate most of the variables had few observations at their extremes. In addition, many of the variables were so highly intercorrelated that, in removing the effect of one or two of them, the effect of those remaining was also removed.

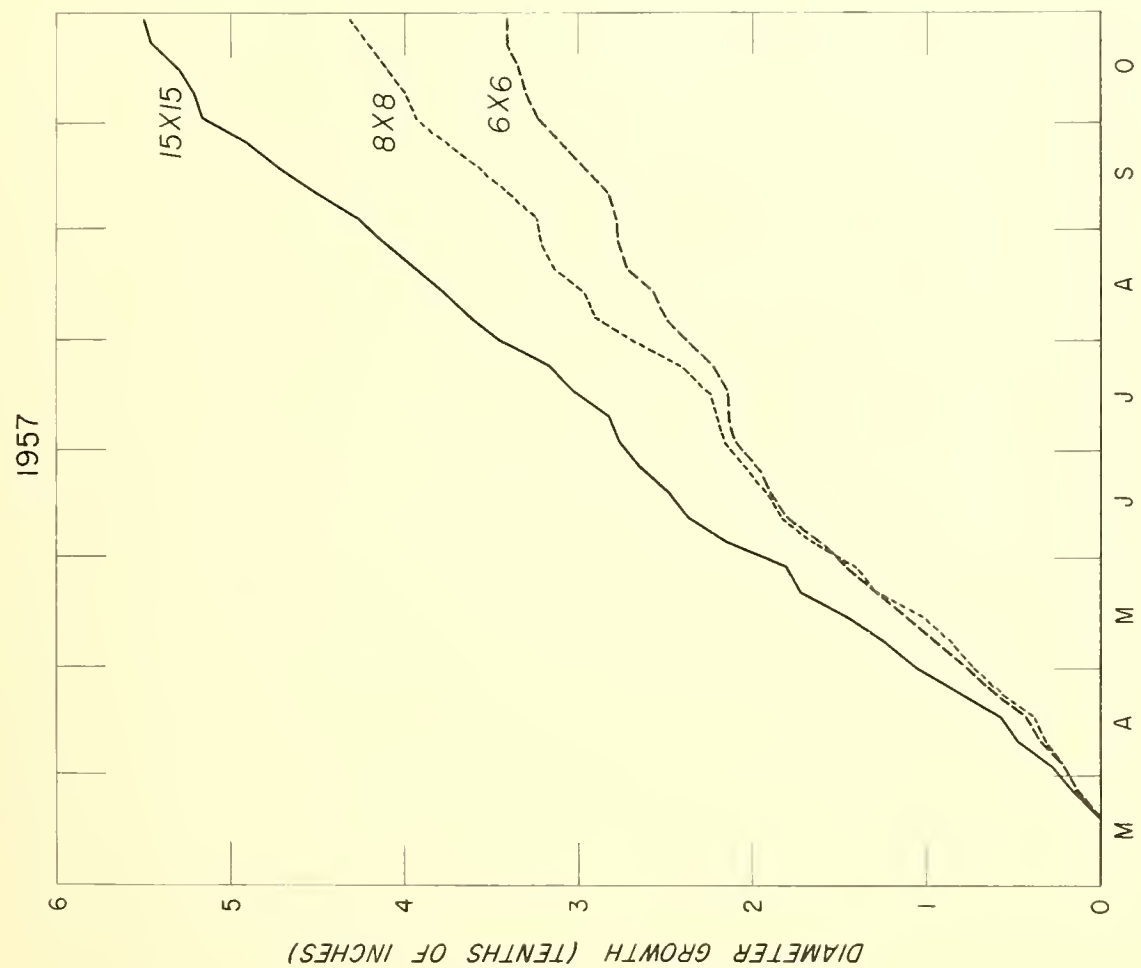
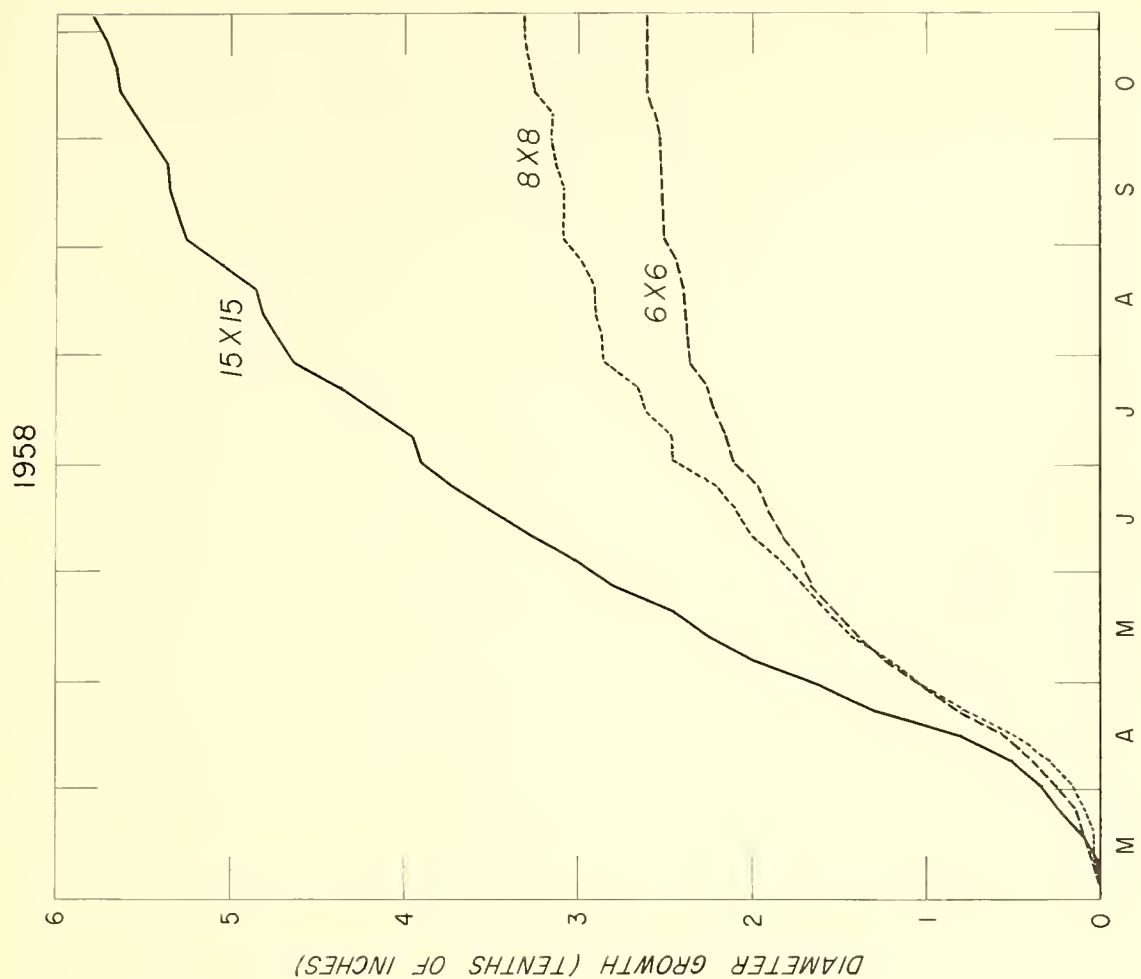


Figure 3. -- Weekly cumulative diameter growth by spacing for 1957 and 1958.

Table 2.--Average initial diameter and average diameter growth of the sample trees on the study plots in 1957 and 1958

Plot	Trees per acre	1957		1958	
		Initial diameter	Diameter growth	Initial diameter	Diameter growth
----- <u>Inches</u> -----					
A 6 x 6	1,210	2.39	0.32	2.82	0.24
B 6 x 6	1,210	2.56	.37	3.07	.29
A 8 x 8	681	2.69	.40	3.19	.32
B 8 x 8	681	2.59	.46	3.17	.34
A 15 x 15	194	3.00	.49	3.59	.57
B 15 x 15	194	3.11	.62	3.79	.59

Table 3.--Initial basal area and basal area growth in square feet per acre on the study plots in 1957 and 1958

Plot	Trees per acre	1957		1958	
		Initial basal area	Basal area growth	Initial basal area	Basal area growth
----- <u>Square feet</u> -----					
A 6 x 6	1,210	37.86	10.63	52.61	9.26
B 6 x 6	1,210	43.89	13.62	62.73	12.60
A 8 x 8	681	27.06	8.63	38.08	8.12
B 8 x 8	681	25.13	9.79	37.44	8.49
A 15 x 15	194	9.61	3.43	13.78	4.78
B 15 x 15	194	10.33	4.48	15.28	5.22

In combining the data for spacing comparisons, variables were chosen from the individual regressions that were significant in at least two of the spacings. For 1957, those chosen were available water, maximum air temperature and its square, and season and its square. The same variables were chosen for 1958 with the addition of evaporation. The linear and quadratic contrasts were added last.

Analysis of variance showed that the environmental variables as well as the linear spacing contrast were highly significant both years, whereas the quadratic spacing contrast and the interactions of linear and quadratic contrasts with the environmental variables were not significant. Significance of the linear and nonsignificance of the quadratic contrast indicates that the relationship between diameter growth and spacing did not differ significantly from a straight line. This is substantiated by Bennett's (1) analysis of diameter growth of the spacing study as a whole. Nonsignificance of interactions of linear and quadratic contrasts with environmental factors indicated that effects of soil moisture, temperature, evaporation, and seasonal effects did not vary from spacing to spacing.

Equations for estimating diameter growth rate were calculated from the regression analyses of data for combined spacings. The equation for 1957 accounted for 57 percent of the variation in growth. The equation for 1958, differing only by addition of a variable expressing evaporation effects, accounted for 75 percent of the variation. Solutions provided an equation for each spacing for each year. Regression coefficients and their standard errors are given in table 4.

Table 4. --Regression coefficients and their standard errors for the diameter growth equations

Variable	1957		1958	
	Coefficient	Standard error	Coefficient	Standard error
6 x 6 constant	-41.595220	± 9.295893	-44.871163	± 9.634372
8 x 8 constant	-41.247577	± 9.293614	-44.314519	± 9.631927
15 x 15 constant	-40.809934	± 9.292520	-43.757875	± 9.630725
Available water	6.305105	± 1.185600	6.102107	± 1.408270
Evaporation	--	--	1.418635	± .468043
Max. air temp.	.999377	± .223824	1.062768	± .244126
(Max. air temp.) ²	- .005634	± .001338	- .007299	± .001500
Season	- .008719	± .001384	.069350	± .017378
(Season) ²	--	--	- .000187	± .000042

DISCUSSION

Growth

It is apparent from these data that differences in diameter growth from spacing to spacing cannot be attributed to measured environmental factors. Although the 15 x 15 grew several weeks longer than the 6 x 6 and 8 x 8 spacings, the nonsignificance of the interaction of spacing and available water indicates that even the effect of moisture on growth did not vary with spacing.

Available water in the profile was adequate for growth throughout most of the study period, dropping to a low of 3 inches only toward the end of the 1958 season. A separate analysis of the soil moisture data showed that moisture was about the same in the 6 x 6 and 15 x 15 spacings, and somewhat higher in the 8 x 8.^{1/} It is likely that root competition had not yet become an important factor, even in the closest spacing. This apparent lack of competition, and a plentiful supply of moisture throughout most of both growing seasons, explains why spacing had no effect on the growth-soil moisture relations. Had there been long periods of severe moisture deficits, especially early in the year, differences in growth between spacings because of moisture might have been significant. The water deficit in the latter part of 1958 undoubtedly influenced growth, but its effect was general, in that growth of all spacings was retarded at about the same time. During the wet 1957 season growth was maintained well into late summer, almost two months longer than in 1958.

These results are not necessarily at variance with Zahner and Whitmore's (14) work in Arkansas where differences in diameter growth of thinned and unthinned loblolly pine plantations were associated with soil moisture as well as with crown and root development. The difference in growing season moisture regimes in the two areas is such that soil moisture becomes limiting much more often in south Arkansas than in middle Georgia. The average June-August rainfall in the coastal plain of Arkansas is 11.7 inches, evenly distributed among the 3 months (12). Extended dry periods occur almost every summer, and available water in the root zone frequently is reduced to near the wilting point by midsummer. Unless rain replenishes soil moisture, considerable growth losses occur (11, 13).

In contrast, summer droughts severe enough to cause noticeable growth losses are much less common in the middle coastal plain of Georgia. Average June-August rainfall is 15.4 inches, with almost half of it coming in July during the peak of the growing season (12). While dry periods do occur, they are of short duration. For this reason the influence of spacing on growth-soil moisture relationships can be expected to be much less pronounced in middle Georgia than in south Arkansas.

^{1/} Harms, W. R. A study of the effect of certain climatic factors on soil moisture and the growth of planted slash pine. Unpublished Ph.D. dissertation, Duke University. 1961.

If moisture were not limiting, growth differences between spacings must have been caused by some other factor. This factor probably was light. Other than soil moisture and perhaps mineral nutrients, it is the only important environmental factor whose influence is strongly, though indirectly, affected by spacing. Since growth of individual trees is conditioned by crown size, which is limited by mutual shading, growth differences between spacings were probably the result of differences in photosynthetic area. Growth and crown ratio measurements taken in 1958 support this assumption in that the 15 x 15 spacing with a crown ratio of 85.4 percent grew 50.3 percent more in diameter than the 6 x 6 with a crown ratio of 57.5 percent, and 43.1 percent more than the 8 x 8 with a crown ratio of 65.3 percent.

During the first 4 years of this plantation there was no difference in diameter growth among spacings. Differences first became apparent at the end of the fifth growing season at a density of 500 to 550 trees per acre (1). At that time the trees averaged 12.6 feet in height and competition for light was just beginning in the 8 x 8 and narrower spacings.

If growth per tree increases with crown surface, as measured by crown ratio, and therefore with spacing, it follows that on a stand or area basis growth also increases with crown surface. However, in this case crown surface on a stand basis is greater on the narrow spacings. This is borne out by the basal area growth data. Over the 2-year period of study basal area growth of the 6 x 6 spacing averaged 11.53 square feet per acre per year, the 8 x 8 spacing 8.76 square feet, and the 15 x 15 spacing 4.48 square feet.

Environmental Factors

The equations presented in table 4 make it possible to study the probable relationship between diameter growth and each of the environmental factors. Curves of diameter growth for each factor for the 8 x 8 spacing were obtained by holding all other variables at their mean value, and calculating growth as a function of the designated variable.

The curves in figure 4 show the average effect of each of the three significant environmental variables. The shapes of these curves should be regarded as general trends applicable only to the data at hand, although they probably approximate those that would be derived whenever similar climatic conditions prevail.

The shape of the available water and temperature curves support the results of past work (5, 6). Diameter growth increased linearly with available water over the range of moistures encountered in the study. Although it is not apparent, the rate of increase in diameter growth with available water was somewhat less in 1958 than 1957. This resulted from drier growing conditions in 1958. As shown in figure 3, growth continued at a high rate well into fall in 1957, but had slowed markedly by mid-July in 1958.

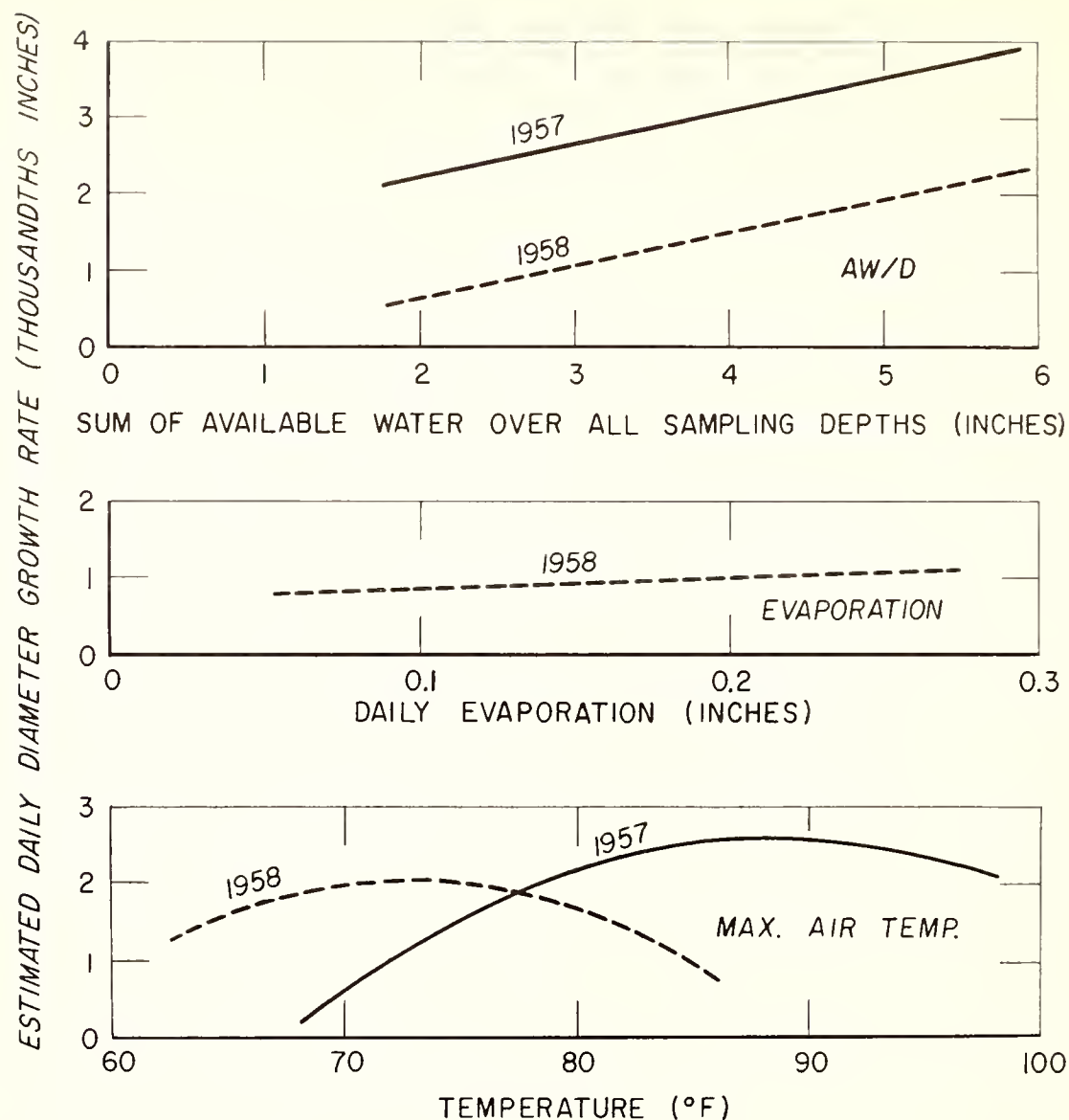


Figure 4. --Estimated daily diameter growth rate of the 8x8 spacing plotted over the several environmental factors with all other factors held at their mean. Each of the factors is designated by the symbols used in the regression equations.

In both years growth increased with maximum air temperature up to a certain point after which higher temperatures were accompanied by a progressive drop in growth. This effect was influenced by the relation between temperature, photosynthesis, and respiration. As temperature increases, photosynthesis soon reaches a maximum rate, under constant light conditions, while respiration continues to increase. The net effect is a decrease in food available for growth. In 1957 growth reached a maximum at a temperature of about 88° F. In 1958 the maximum was 73° F. The rate of growth increased more rapidly with temperature in 1957 than in 1958. The difference in general climatic conditions between the 2 years does not appear to be great enough to account for such a large drop in the temperature effect. It is likely that the difference in temperature effect was due to a temperature-soil moisture interaction. In 1957, water deficits were considerably less severe than in 1958. Evidently when the soil is moist, temperature can be higher before it becomes limiting to growth.

Growth was positively correlated with evaporation. The effect of evaporation on growth is expressed indirectly through its relation to the evaporating power of the air which in turn influences the rate of transpiration. Under conditions of high transpiration rates, absorption of water by the roots may lag behind water loss through the leaves even when soil moisture is adequate. This will result in a decrease in the turgidity of the cells, stomatal closure, and a reduction in the rate of photosynthesis. Any of these conditions will check growth.

It is surprising therefore that the analysis shows a positive relation between growth and evaporation. Possibly this situation can be explained by the fact that high evaporation rates occur on bright, sunny days, a condition which favors growth if moisture is not limiting. Also, there is a strong correlation between evaporation and temperature, because both factors tend to increase together.

SUMMARY AND CONCLUSIONS

Multiple regression methods were used to study the influence of plantation spacing on the relationships between certain environmental factors and the diameter growth of young slash pine in the middle coastal plain of Georgia.

The study was made during the sixth and seventh growing seasons in a plantation planted at spacings of 6 x 6, 8 x 8, and 15 x 15 feet. Diameter growth was measured weekly and soil moisture at 2- to 3-day intervals. Soil and air temperature, relative humidity, evaporation, wind, and rainfall measurements were made at a weather station installed near the plantation.

Significant correlations were found between diameter growth and available soil moisture, maximum air temperature, evaporation, and elapsed days from January 1. None of these factors explained the differences in diameter growth between spacings. Differences were attributed to the interaction of light and photosynthetic surface. Photosynthetic surface of the trees, as measured by crown ratio, increased with spacing; under the same light conditions individual trees on the wide spacing produced more food for growth than those on the close spacing.

Whereas competition for light had begun in the close spacing during the fifth year, root competition, and therefore competition for soil moisture, was not yet apparent during the sixth and seventh years. The rate of change of diameter growth with change in soil moisture was uniform for all spacings.

The growing season moisture regime of the middle coastal plain of Georgia is such that soil moisture probably is not a very serious limiting factor in plantations at this age even at close spacings, though it may become important as the stand develops.

LITERATURE CITED

- (1) Bennett, Frank A.
1960. SPACING AND EARLY GROWTH OF PLANTED SLASH PINE. Jour. Forestry 58:966-967.
- (2) Boggess, W. R.
1953. DIAMETER GROWTH OF SHORLEAF PINE AND WHITE OAK DURING A DRY SEASON. Univ. Ill. Agr. Expt. Sta. Forestry Note 37.
- (3) _____
1956. WEEKLY DIAMETER GROWTH OF SHORLEAF PINE AND WHITE OAK AS RELATED TO SOIL MOISTURE. Soc. Amer. Foresters Proc. 1956:83-89.
- (4) Della-Bianca, L., and Dils, R. E.
1960. SOME EFFECTS OF STAND DENSITY IN A RED PINE PLANTATION ON SOIL MOISTURE, SOIL TEMPERATURE AND RADIAL GROWTH. Jour. Forestry 58:373-377.
- (5) Fritts, H. C.
1958. AN ANALYSIS OF RADIAL GROWTH OF BEECH IN A CENTRAL OHIO FOREST DURING 1954-1955. Ecology 39:705-720.
- (6) _____
1960. MULTIPLE REGRESSION ANALYSIS OF RADIAL GROWTH IN INDIVIDUAL TREES. Forest Sci. 6:334-349.
- (7) Liming, F. G.
1957. HOMEMADE DENDROMETERS. Jour. Forestry 55:575-577.
- (8) McClurkin, D. C.
1958. SOIL MOISTURE AND SHORLEAF PINE RADIAL GROWTH IN NORTH MISSISSIPPI. Forest Sci. 4:232-238.
- (9) _____
1961. SOIL MOISTURE TRENDS FOLLOWING THINNING IN SHORLEAF PINE. Soil Sci. Soc. Amer. Proc. 25:135-138.
- (10) Olson, D. F., Jr., and Hoover, M. D.
1954. METHODS OF SOIL MOISTURE DETERMINATION UNDER FIELD CONDITIONS. U. S. Forest Serv. Southeast. Forest Expt. Sta. Paper 38, 28 pp.
- (11) Reynolds, R. R.
1958. DROUGHT CAN BE COSTLY TO TIMBER-LAND OWNERS. South. Lumberman 196(2447):32-33.
- (12) U. S. Department of Agriculture
1941. CLIMATE AND MAN. U. S. Dept. Agr. Yearbook 1941, 1248 pp.
- (13) Zahner, R.
1956. THE TIMBER GROWERS STAKE IN WATER. Forest Farmer 16(2):9, 34.
- (14) _____ and Whitmore, F. W.
1960. EARLY GROWTH OF RADICALLY THINNED LOBLOLLY PINE. Jour. Forestry 58:628-634.

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